PLACE, SPACE, AND POLICE INVESTIGATIONS: HUNTING SERIAL VIOLENT CRIMINALS

by

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Abstract: *Police investigations of serial murder, rape and arson can be assisted by a geographic perspective on the spatial behavior that led to the crime scene. For any crime to occur there must have been an intersection in both time and place between the offender and victim. How did this come to happen? What are the hunting patterns of predatory criminals? Environmental criminology and the routine activity approach provide a general framework for addressing these questions, and work in this area represents a practical application of theory to the real world of police investigation. By "inverting" research that has focused on relating crime places to offender residences, the locations of a series of crimes can be used to determine where an offender might reside. The probable spatial behavior of the offender can thus be derived from information contained in the known crime-site locations, their geographic connections, and the characteristics and demography of the surrounding areas. By determining the probability of the offender residing in various areas, and displaying those results through the use of isopleth or choropleth maps, police efforts to apprehend criminals can be assisted. This investigative approach is known as geographic profiling.*

INTRODUCTION

A focus of any police investigation is the crime scene and its evidentiary contents. What is often overlooked, however, is a geographic perspective on the actions preceding the offense: the spatial behavior that led to the crime scene. For any violent crime to occur there must have been an intersection in both time and place between the victim and offender. How did this happen? What were the antecedents? What do the spatial elements of the crime tell us about the offender and his or her actions?

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What are the hunting patterns of predatory offenders? These questions are particularly relevant in cases of serial murder, rape and arson.

Environmental criminology and routine activity theory provide a general framework for addressing these questions. In addition, the model of crime-site selection developed by Brantingham and Brantingham (1981) suggests a specific approach for determining the most probable location of offender residence in cases of serial violent crimes. Research in this area represents a practical application of criminological theory to the real world of police investigation, which not only can contribute useful information to law enforcement agencies but may also open up possibilities for new and innovative investigative methodologies.

The nature of serial violent crime creates unique problems for law enforcement, requiring special police responses and investigative strategies. Klockars (1983) asserts that there are only three ways to solve a crime: (1) a confession, (2) a witness and (3) physical evidence. Traditionally, the search for witnesses, suspects and evidence has followed a path, originating from the victim and the crime scene outward. Most homicides, for example, are cleared for the simple reason that they involve people who know each other, and the process of offender identification is often only one of suspect elimination.

Such obvious connections rarely exist in cases of stranger crimes. The lack of any relationship between the victims and the offender makes these crimes difficult to solve. In conducting these types of investigations working outward from the victim is a difficult task. The alternative, then, is to work inward, trying to establish some type of link between potential suspects and the victim or crime scene. This process requires the delineation of a likely group of potential suspects; such efforts, however, can produce lists often numbering into the thousands, causing problems with information overload. In the still unsolved Seattle-area Green River Killer case, for example, 18,000 suspect names have been collected. But as of February 1992, the police have only had the time and resources to investigate some 12,000 of these (Montgomery, 1992). The Yorkshire Ripper case had, by the time it was solved, 268,000 names in the nominal index (Doney, 1990).

Clues derived from crime location and place can be of significant assistance to law enforcement in the investigation of repetitive offenses. The probable spatial behavior of the offender can be derived from information contained in the known crime site locations (e.g., encounter/apprehension sites, murder scenes, body/property dump sites), their geographic connections, and the characteristics and demography of the surrounding neighborhoods. Determining the probability of the offender residing in various areas, and displaying those results through the use of choropleth or isopleth maps, can assist police efforts to apprehend criminals. This information allows police departments to focus their investigative activities, geographically prioritize suspects and concentrate saturation or directed patrolling efforts in those zones where the criminal predator is most likely to be active. Such investigative approaches have been termed geographic profiling (Rossmo, 1995) or geoforensic analysis (Newton and Newton, 1985).

ENVIRONMENTAL CRIMINOLOGY

Traditionally, the main interest of criminology has been the offender, and much effort has gone into studying offender backgrounds, peer influences, criminal careers and deterrence. This focus has tended to ignore the other components of crime—the victim, the criminal law and the crime. The crime setting or place, the "where and when" of the criminal act, makes up what Brantingham and Brantingham (1981) call the fourth dimension of crime—the primary concern of environmental criminology. "Environmental criminologists set out to use the geographic imagination in concert with the sociological imagination to describe, understand, and control criminal events" (Brantingham and Brantingham, 1981:21). The roots of this perspective lie in human ecology, Jeffery's bio-social learning approach and Hirschi's social control theory (Brantingham and Brantingham, 1981; Void and Bernard, 1986).

Research in this area has taken a broad approach by including in its analyses operational, perceptual, behavioral, physical, social, psychological, legal, cultural, and geographic settings. These works range from micro to meso to macrospatial levels of analytic focus. One of environmental criminology s major interests, the study of the dimensions of crime at the microspatial level, has often led to useful findings in the area of crime prevention (see, for example, Clarke, 1992). Other projects have included the analyses of: crime trips (Rhodes and Conly, 1981); efforts to understand target and victim selections through opportunities for crime (Brantingham and Brantingham, 1981); crime prevention initiatives, notably crime prevention through environmental design (Jeffery, 1977; Wood, 1981); proposals for rapid transit security (Felson, 1989); patterns of fugitive migration (Rossmo, 1987); and other methods (see Clarke, 1992).

The spatial relationship between the offender's home and his or her crimes is an underlying theme in much of this work. Is it possible to "invert" this research and use the locations of a series of crimes to suggest where an offender might reside? By reversing the reasoning and logic of these theoretical models, it may be feasible to predict the most probable location of a criminal's residence. Such a result would allow the principles of environmental criminology and the geography of crime to be practically applied to the police investigative process.

GEOGRAPHY AND CRIME INVESTIGATION

While police officers are intuitively aware of the influence of place on crime, they sometimes are unaware of the different ways in which geography can assist their work. In spite of this general lack of understanding, however, there are some specific examples of the use of geographic principles by the police in efforts to investigate crimes and apprehend suspects.

Some police dog handlers, for instance, have noted patterns in the escape routes and movements of offenders fleeing from the scenes of their crimes (Eden, 1985). This predictability in the movements of those under stress has been observed in both actual trackings of suspects and experimental reenactments using police dog quarries. Fleeing criminals tend to turn to the left if they are right-handed, move to the right upon encountering obstacles, discard evidentiary items to their right and stay near the outside walls when hiding in large buildings (Eden, 1985). Different patterns are found when conducting passive tracks for missing persons. Lost subjects tend to bear to the right in their wanderings, and men seem to favor downhill paths while women and children choose uphill routes (Eden, 1985).

Senior Superintendent Arvind Verma describes how the Indian Police Service in the Bihar province have used a form of geographical analysis in the investigation of certain types of crimes. *Dacoities* are robberies with violence involving gangs of five or more offenders. This type of criminal act dates back to 500 BC and usually occurs in the countryside. The lack of anonymity in a rural setting requires the *dacoity* gang to attack villages other than their own, and then only during those nights when the moon is new. There is usually little or no artificial lighting in rural India, and the lunar dark phase is a period of almost complete blackness that provides cover for such criminal activities.

Upon being notified of a *dacoity*, the police will first determine the length of time between the occurrence of the crime and first light. Knowing the average speed that a person can travel cross-country on foot then allows the police to calculate a distance radius, centered on the crime site, which determines a circle within which the home village of the *dacoity* members most probably lies. There are few vehicles and if the criminals are not home by daylight, they run the risk of being observed by farmers who begin to work the fields at dawn.

The villages located within this circle can then be narrowed down by eliminating those of the same caste as the victim village, as "brother" is not likely to harm "brother." And, if a sufficiently detailed description of the criminals can be obtained, dress, modus operand! and other details can help determine the caste of the gang, allowing the police to concentrate further on the appropriate villages. Patrols can then speed to these places and attempt to intercept the *dacoity* members, or to proceed to investigate known criminal offenders residing in the area.

In an effort to focus the Hillside Strangler investigation, the Los Angeles, CA Police Department (LAPD) attempted to determine the most likely location of the scene of the homicides. The police knew where the victims had been apprehended and where their bodies had been dumped, and the distances between these two points (Gates and Shah, 1992). The LAPD computer analysts viewed the problem in terms of Venn diagrams, with the center of each circle representing victim availability, the circumference representing offender capacity and the radius representing offender ability (Holt, 1993).

Vectors drawn from the point where the victims were abducted to the location where their bodies were found were added together to produce a common radius, which defined a circle encompassing an area of just over three square miles. The LAPD saturated this zone with 200 police officers in an attempt to find the murderers. While they were not successful, it is possible that the heavy police presence inhibited the killers, and prompted murderer Kenneth Bianchi's move from Los Angeles to Bellingham, WA. The center of this zone, the LAPD later found out, was not far from co-murderer Angelo Buono's automobile upholstery shop-cum-residence (Gates and Shah, 1992).

Geographic techniques were also used in the Yorkshire Ripper investigation. With the murders still unsolved after five and one-half years, Her Majesty's Inspector of Constabulary Lawrence Byford implemented a case review process (Kind, 1987a). Detectives had become divided over the issue of the killer's residence. One school of thought, led by the chief investigating officer, believed that the Ripper was from the Sunderland area, while other investigators thought he was a local man. After an intensive investigative review, the Byford advisory team came to the latter conclusion.

To help test this deduction, they applied two "navigational metrical tests" to the spatial and temporal data associated with the crimes (Kind, 1987a:388-390). The first test involved the calculation of the center of gravity (spatial mean) for the 17 crimes (13 murders and four assaults) believed to be linked to the Yorkshire Ripper. The second test consisted of plotting time of offense against length of day (approximated by month of year). The rationale behind this approach had its basis in the theory that the killer would not be willing to attack late at night if his return journey to home was too far.

The first navigational test resulted in the finding that the center of gravity for the Ripper attacks lay near Bradford. The second test determined that the later attacks were those located in the West Yorkshire cities of Leeds and Bradford. Both tests therefore supported the team's original hypothesis that the killer was a local man. Peter William Sutcliffe, who resided in the district of Heaton in the city of Bradford, was arrested three weeks later by a patrol constable and sergeant in Sheffield.

Newton and Newton (1985) applied what they termed geoforensic analysis to a series of unsolved female homicides that occurred in Fort Worth, TX from 1983 to 1985. They found that localized serial murder or rape tends to form place-time patterns different from those seen in "normal" criminal violence. The unsolved Fort Worth murders were analyzed by employing both quantitative (areal associations, crime site connections, centrographic analysis), and qualitative (landscape analysis) techniques.

Newton and Swoope (1987) also utilized geoforensic techniques in a retrospective analysis of the Hillside Strangler case. Different geographic centers were calculated from the coordinates of the locations of various types of crime sites. They discriminated between points of fatal encounter, body or car dump sites and victim's residences, and found that the geographic center of the body dump sites most accurately predicted the location of the residence of murderer Angelo Buono's. A search radius (circumscribing an area around the geographic center in which the killers were thought to most likely be found) was also calculated, the range of which decreased with the addition of the spatial information provided by each new murder.

CRIMINAL GEOGRAPHIC TARGETING

The locations where crimes happen are not completely random, but instead often have a degree of underlying spatial structure. As chaotic as they may sometimes appear to be, there is often a rationality influencing the geography of their occurrence. Routine activity theory suggests that crimes tend to occur in those locations where suitable (in terms of profit and risk) victims are encountered by motivated offenders as both move through their daily activities (Clarke and Felson. 1993; Cornish and Clarke, 1986; Felson, 1986, 1987). As offenders travel among their homes, workplaces, and social activity sites, their activity space (composed of these locations and their connecting paths) describes an awareness space that forms part of a larger mental map—an "image of the city" built upon experience and knowledge.

Within a person's activity space is usually an anchor point or base, the single most important place in their spatial life. For the vast majority of people this is their residence. For others, however, the anchor point may be elsewhere, such as the work site or a close friend's home. It should be remembered that some street criminals do not have a permanent residence and may base their activities out of a bar, pool hall or some other such social activity location (Rengert, 1990). They might also be homeless, living on the street, or may be transient or mobile to such a degree that they lack any real form of anchor point.

Brantingham and Brantingham (1981) suggest that the process of criminal target selection is a dynamic one. Crimes occur in those locations where suitable targets are overlapped by the offender s awareness space. Offenders may then move outward in their search for additional targets, their interactions decreasing with distance. Search pattern probabilities can thus be modeled by a distance-decay function that show an inverse relationship between the level of interactions and the distance from the locations and routes that comprise the activity space. There may also be a "buffer zone" centered around the criminal's home, within which the offender sees targets as being too risky to victimize because of their proximity to his or her residence (cf. Newton and Swoope, 1987).

The Brantingham and Brantingham (1981) model predicts, for the simplest case, that the residence of the offender would lie at the center of the crime pattern and therefore could be approximated by the spatial mean. The intricacy of most activity spaces, however, suggests that more complex patterns may be appropriate. Rengert (1991) proposes four hypothetical spatial patterns that could be used to describe the geography of crime sites: (1) a uniform pattern with no distance-decay influence; (2) a bull's-eye pattern with spatial clustering, exhibiting distance-decay, centered around the offender's primary anchor point; (3) a bimodal pattern with crime clusters centered around two anchor points; and (4) a teardrop pattern with a directional bias oriented toward a secondary anchor point.

Situations can also be distorted by a variety of other real world factors—movement often follows street grids, traffic flows can distort mobility patterns, variations exist in zoning and land use, and crime locations may cluster depending upon the nature of the target backdrop (i.e., the spatial distribution of targets or victims). The spatial mean is therefore limited in its ability to pinpoint criminal residence.

However, combining centrographic principles and journey to crime research in a manner informed by environmental criminological theory can produce a viable method for predicting the location of offender residence from crime site coordinates. One such effort is criminal geographic targeting (CGT), a computerized geographic profiling technique used in police investigations of complex serial crimes (Rossmo, 1993). By examining the spatial data connected to a series of crime sites, the CGT model generates a three-dimensional surface, the "height" of which represents the relative probability that a given point is the residence or workplace of the offender.

Criminal geographic targeting is based on the Brantingham and Brantingham (1981) model for crime site selection and on the routine activities approach (Felson, 1986). It uses a distance-decay functioned) that simulates journey to crime behavior. A probability value *J[dd* is assigned to each point (x, *y),* located at distance *d* from crime site *i.* The final probability value for a point (x, y), representing the likelihood that the offender lives at that location, is determined by adding together the n values derived at that point from the *n* different crime sites.

The use of CGT in actual police investigations—and tests of the model on solved cases of serial murder, rape and arson—have produced promising results, usually locating the offender's residence in the top 5% or less of the total hunting area. The model is based on a four-step process:

(1) Map boundaries delineating the offender's hunting area are first established using the locations of the crimes and standard procedures for addressing edge effects.

(2) Manhattan distances (i.e., orthogonal distances measured along the street grid) from every "point" on the map, the number of which is determined by the measurement resolution of the x and *y* scales, to each crime location are then calculated.

(3) Next, these Manhattan distances are used as independent variable values in a function that produces a number that: (a) if the point lies outside the buffer zone, becomes smaller the longer the distance, following some form of distance-decay; or (b) if the point lies inside the buffer zone, becomes larger the longer the distance. Numbers are computed from this function for each of the crime locations. For example, if there are 12 crime locations, each point on the map will have 12 numbers associated with it.

(4) Finally, these multiple numbers are multiplied together to produce a single score for each map point. The higher the resultant score, the greater the probability that the point contains the offender's residence.[1]

Figure 1: Three-Dimensional Isopleth Map of San Diego Serial Rapist (LeBeau, 1992)

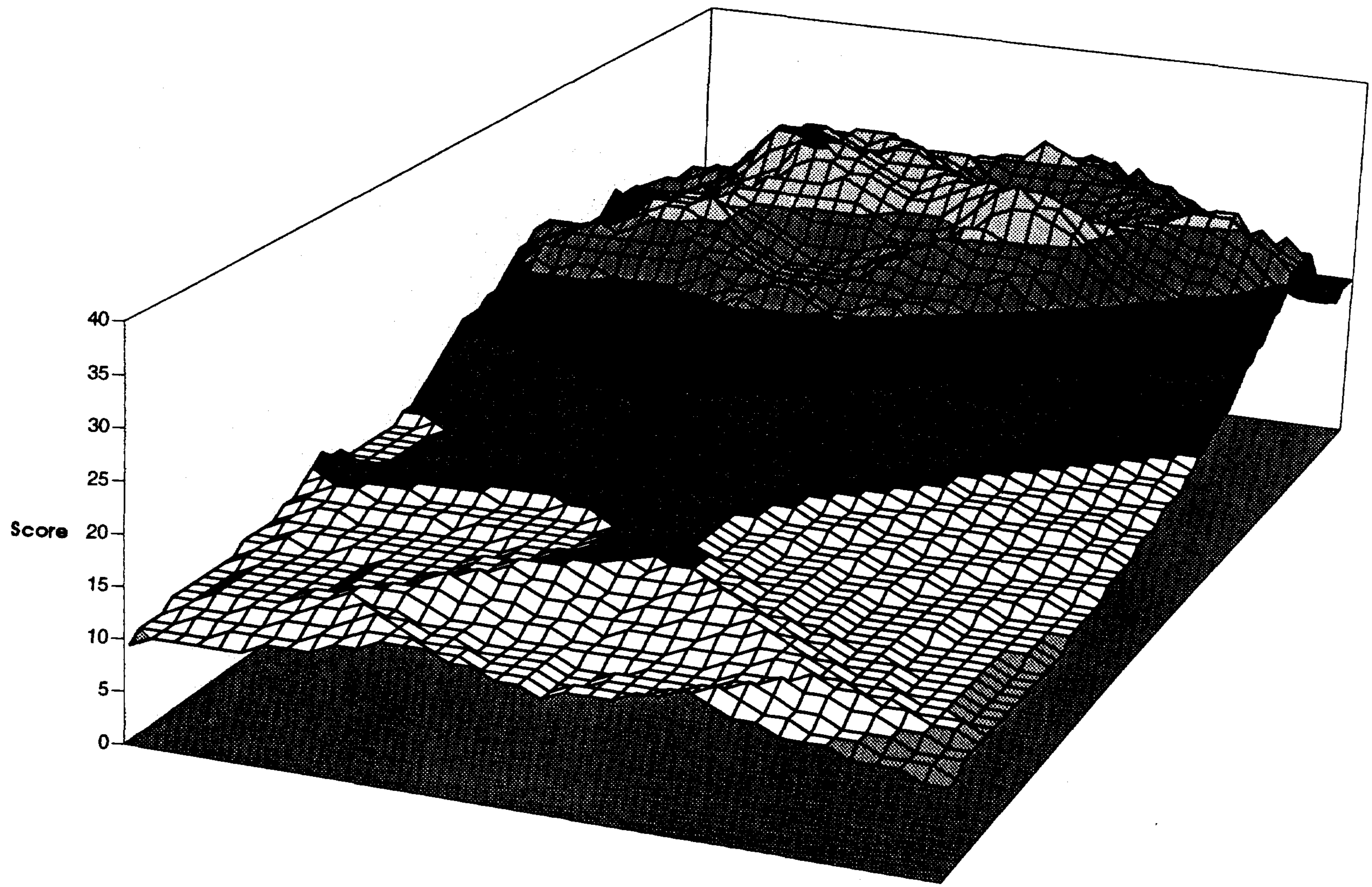
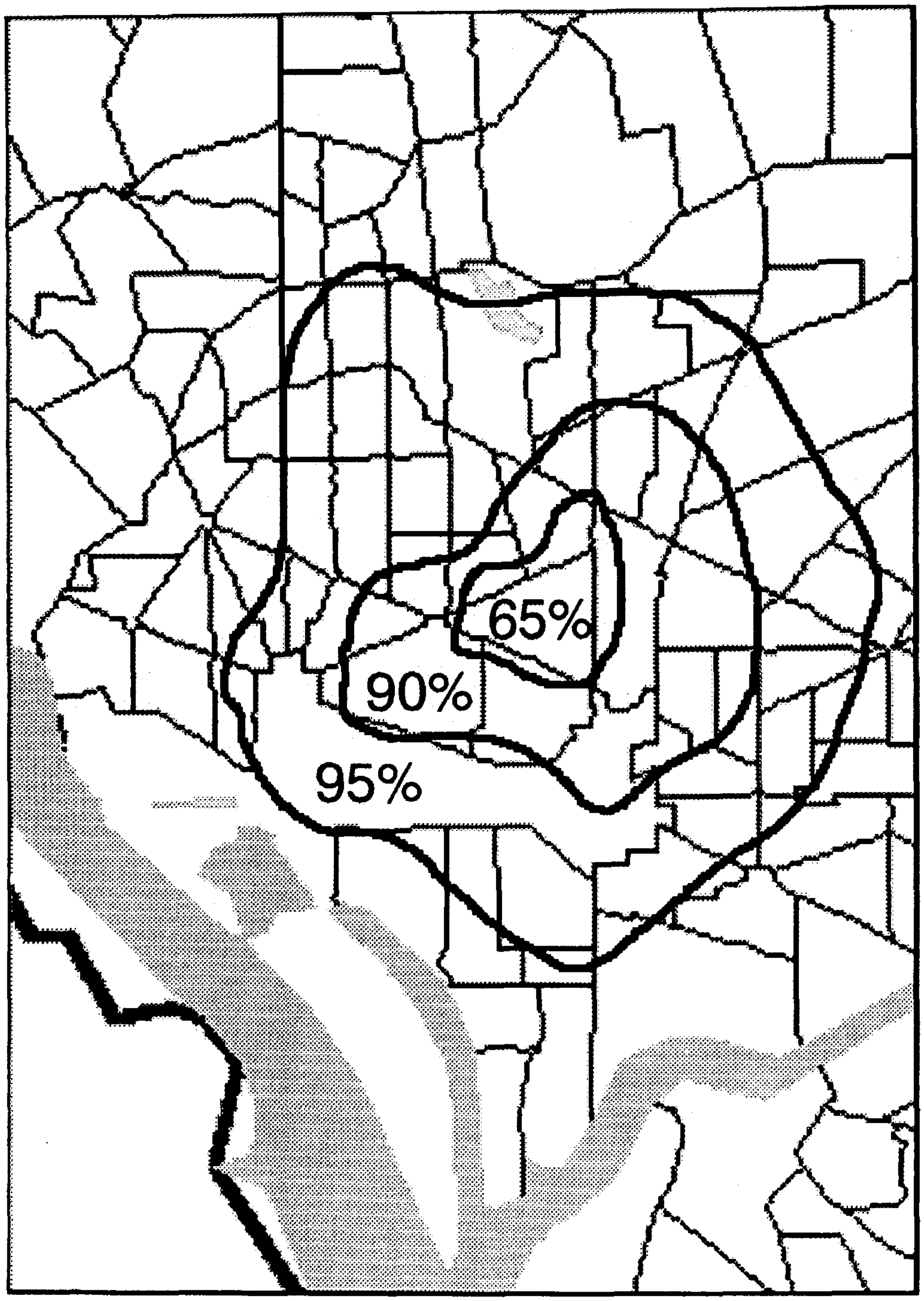


Figure 2: CGT Choropleth Probability Map



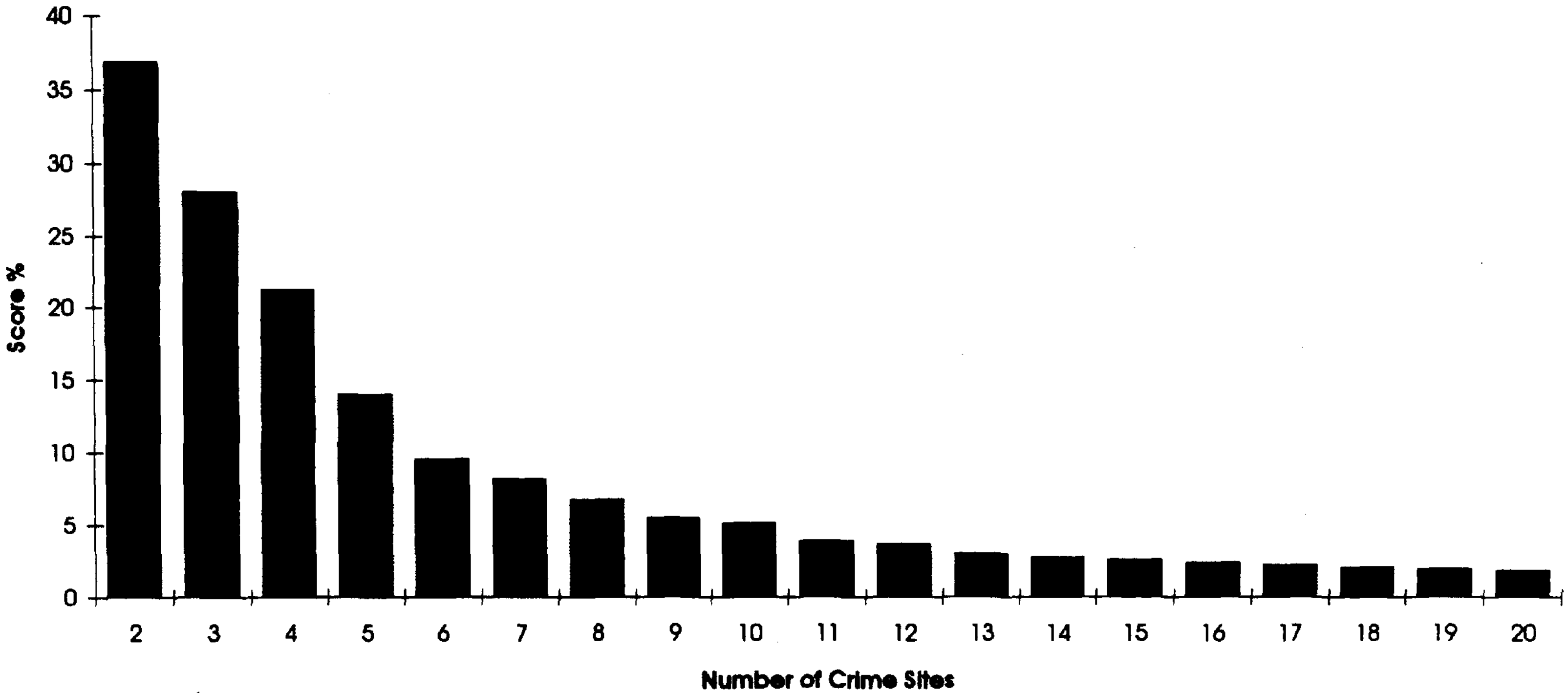
When the probabilities are calculated for every point on the map, the end result is a three-dimensional probability surface that can be represented by an isopleth map. Figure 1 shows an example of such a surface derived from the crime locations of a serial rapist in San Diego, CA (LeBeau, 1992). An isopleth graph shows the value of one variable (in this instance, probability scores) as a function of two other variables (in this instance, north-south and east-west distances). Continuous lines mark out areas of equal probability much as contour lines mark out areas of equal altitude on a relief map. Alternatively, if viewed from above, the probability surface can be depicted by a two-dimensional choropleth map (Harries, 1990). In the latter case, the result can be overlaid on a city map of the involved area, and specific streets or blocks prioritized according to the associated values shown on the CGT choropleth probability map (see Figure 2; this is a hypothetical case involving a crime series in the District of Columbia).

Any methodology, whether investigative or scientific, should meet three important criteria: validity, reliability and utility. The CGT model works on the assumption that a relationship, modeled on some form of distance-decay function, exists between crime location and offender residence. The process can be thought of as a mathematical method for assigning a series of scores to the various points on a map that represents the serial offender's hunting area. Since the model cannot locate the residence of a criminal that lies outside of the boundaries of the hunting area map, it is necessary to limit the process to non-commuting offenders.

For the CGT model to be valid, the score it assigns to the point containing the offender's residence should be higher than the scores for most of the other points on the hunting area map. How well this requirement is met can be examined with a distribution curve that indicates the number of points with various scores. The "success" of the CGT model in a given case can then be measured by determining the ratio of the total number of points with equal or higher scores to the total number of points in the hunting area. In other words, in what percentage of the total area would the offender's residence be found by a process that started in the locations with the highest scores and then worked down? The smaller that percentage (referred to as the "hit percentage"), the more successful the model.

While the geographic pattern for a crime series may yield several forms of information (coordinates, crime location type, area characteristics, nearest neighbor distances, point pattern, clustering, temporal ordering, etc.), the randomness inherent in most human behavior limits the conclusions that can be derived from a small number of crime sites. The use of more locations reduces the impact of chance. The performance of the

Figure 3: CGT Model Learning Curve



CGT model is thus related to the number of points available for analysis—the more crime locations, the more information and, therefore, the more precision. Validity of the CGT model is hence a function of the number of crime locations.

Monte Carlo testing (a heuristic method that uses repeated simulations), accomplished through a computer program that creates random crime site coordinates based on a buffered distance decay function, was conducted to estimate the theoretical maximum efficiency of the model. The testing produced the "learning curve" shown in Figure 3, which displays the relationship between the number of crime sites available for analysis and the hit percentage produced by the CGT model. This process established that at least six crime locations are necessary to produce hit percentages under 10%.

The reliability of the CGT model is high, as the calculations are mathematically straightforward and the procedure has been computerized. The determination of exactly which crime locations in a given case are relevant to the analysis, however, is a subjective process dependent upon the knowledge, experience and interpretation of the profiler. The qualitative dimensions of geographic profiling are also subject to personal biases.

No matter how valid or reliable a particular investigative technique, it will have little practical value if it cannot be effectively used by police detectives in the real world of crime investigation. The utility of the CGT model is best demonstrated by the various geographically based investigative strategies that such a process makes possible. Some examples of these are described in the following section.

INVESTIGATIVE STRATEGIES

Once a geographic profile has been constructed, a variety of criminal investigative strategies can be employed in a more effective and efficient manner. While the specific approaches are best determined by the police investigators familiar with the case in question, some examples of tactics used or suggested in the past are presented below. The development of further spatially based applications and innovative investigative techniques is an interactive process which involves the police officers responsible for the case in question.

Suspect Prioritization

If a lengthy list of suspects has been developed, the geographic profile in conjunction with the criminal offender profile can help prioritize individuals for follow-up investigative work. The problem in many serial violent crime investigations is one of too many suspects rather than too few. Profiling can help prioritize lists of sometimes hundreds if not thousands of suspects, leads and tips.

Patrol Saturation

Areas that have been determined to most probably be associated with the offender can be used as a basis for directed or saturation police patrolling efforts. This strategy is particularly effective if the offender appears to be operating during certain time periods. Prioritized areas can also be employed for neighborhood canvassing efforts, area searches, information sign posting, and community cooperation and media campaigns. Police departments have used this approach to target areas for leaflet distribution, employing prioritized letter carrier walks for strategic household mail delivery. For example, LeBeau (1992) mentions the case of a serial rapist in San Diego who was arrested through canvassing efforts in an area determined from the locations of his crimes.

Police Information Systems

Additional investigative leads may be obtained from the information contained in various computerized police dispatch and record systems (e.g., computer-aided dispatch systems, records management systems, the Royal Canadian Mounted Police Information Retrieval System, and the like). Offender profile details and case specifics can help focus the search at this point.

For example, the police may be investigating a series of sexual assaults that have been psychologically profiled as the crimes of an anger retaliatory rapist. Such an offender is "getting even with women for real or imagined wrongs.... the attack is an emotional outburst that is predicated on anger" (Hazelwood, 1987:178-179). His rapes are often initiated by conflicts with a significant woman in his life, and he will frequently select victims who symbolize the source of that conflict. One possible investigative strategy, then, is a search of police dispatch data for domestic disturbance calls near the dates of the rapes to see which ones originated from the area where the geographic profile suggests that the offender most likely resides.

Those police agencies that maintain computerized records detailing the descriptions, addresses and modus operandi of local offenders can also use profiling information, including probable area of residence, as the basis for developing search criteria. Many departments have such files for specific types of criminals, such as parolees or sex offenders.

Outside Agency Databases

Data banks, which are often geographically based, as well as information from parole and probation offices, mental health outpatient clinics, social services offices and similar agencies located in the most probable areas can also prove to be of value. For example, LeBeau (1992) discusses the case of a serial rapist who emerged as a suspect after the police checked parolee records for sex offenders.

Zip/Postal Code Prioritization

The geographic profile can also prioritize zip or postal codes in a city. If suspect offender description or vehicle information exists, prioritized zip or postal codes (representing the most probable 1 or 2% of a city's area) can be used to conduct effective off-line computer searches of registered vehicle or driver's licence files contained in provincial or state motor vehicle department records. These parameters act as a form of linear program to produce a surprisingly small set of records containing fields with all the appropriate data responses. Such a strategy can therefore produce significant results by focusing on limited areas that are of a manageable size for most serious criminal police investigations.

The following is one example of the use of this approach. The postal codes for a city neighborhood within which a violent sexual offender was attacking children were prioritized by using the criminal geographic targeting model. Planning and zoning maps were used to eliminate industrial, commercial and other non-residential areas. Socioeconomic and demographic census data were also consulted to reevaluate the priority of those neighborhoods that were inconsistent with the socioeconomic level of the offender, as suggested by a previously prepared psychological profile.

The remaining postal codes, ranked by priority of probability, were then used to conduct an off-line computer search of the provincial motor vehicle department records that contain postal codes within the addresses connected to the vehicle registered owner and driver's licence files. Suspect vehicle information and an offender description had been developed by the detectives working on the case, and this was combined with the geographic data to effectively focus the off-line search. The conjunction of such parameters can narrow down hundreds of thousands of records to a few dozen vehicles or drivers—sufficient discrimination to allow a focused follow-up by police investigators.

Task Force Computer Systems

Task force operations that have been formed to investigate a specific series of major crimes usually collect and collate their information in some form of computerized system. Often these operations suffer from information overload and can benefit from the prioritization of data and the application of correlation analysis. Geographic profiling can assist in these tasks through the prioritization of street addresses, postal or zip codes, and telephone number areas. The details of the specific computer database software used by the task force, including information fields, search time, number of records, and correlational abilities, determine the most appropriate form that the geographic profile should take to maximize its usefulness to the police investigation.

CONCLUSION

Geographic profiling infers spatial characteristics of the offender from target patterns. This method uses qualitative and quantitative approaches that attempt to make sense of the pattern from both subjective and objective perspectives. Criminal geographic targeting is a specific statistical method that enhances the efforts of geographic profiling by delineating the most probable areas to which the offender might be associated.

Since geographic profiling is based on an analysis of crime- site locations, a linkage analysis is a necessary prerequisite to determine which crimes are part of the same series and should be included in the development of the profile. It must also be noted that not all types of offenders or categories of crime can be geographically profiled. In appropriate cases, however, such a spatial analysis can produce very practical results from the police perspective. There are a variety of ways which geographic information about the offender can assist the investigation, including the prioritization of suspects by address or area, the direction of patrol saturation efforts and the establishment of computerized database search parameters.

Geographic profiling therefore appears to have significant investigative value in certain types of criminal cases. It is also an example of the application of criminological theory to a criminal justice problem. Through a process of "inverting" criminological and geographic research that has focused on relating crime places to offender residences, the locations of a series of crimes can be used to suggest where an offender might reside.

Environmental criminology, because of its rich context and diverse roots, has been particular fruitful in the development of practical applications and holds the promise of many future ideas for crime prevention and policing.

1. **The function is of the form:**

$$P_{ij} = \prod_{c=1}^{T} k\,[\phi/(|x_i - x_c| + |y_j - y_c|)^f + (1 - \phi)(B^{g-f})/(2B - |x_i - x_c| - |y_j - y_c|)^g]$$

where:

$$|x_i - x_c| + |y_j - y_c| > B \supset \phi = 1$$

$$|x_i - x_c| + |y_j - y_c| \leq B \supset \phi = 0$$

and:

P_{ij}	**is the resultant probability for point ij;**
k	**is an empirically determined constant;**
B	**is the radius of the buffer zone;**
T	**is the total number of crime sites;**
f	**is an empirically determined exponent;**
g	**is an empirically determined exponent;**
x_i, y_j	**are the coordinates of point ij; and**
x_c, y_c	**are the coordinates of the cth crime site location.**

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